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DESIGN AND DEVELOPMENT OF HYDRAULICALLY OPERATED SLAG REMOVER FOR STEEL FURNACE

N. NAGABHUSHANA RAMESH[1], MD. ABDUL FAHAD[2] & R. VENKAT REDDY[3]

[1]*Research Scholar & Professor, Department of Mechanical Engineering, Anurag Group of Institutions, Hyderabad, Telangana, India*

[2]*Student, Department of Mechanical Engineering, Anurag Group of Institutions, Hyderabad, Telangana, India*

[3]*Research Scholar, Professor& Head, Department of Mechanical Engineering, Anurag Group of Institutions, Hyderabad, Telangana, India*

ABSTRACT

The present work is about the invention of hydraulically operated slag remover, which works to remove the slag from the furnace while the material is burning in the furnace for proper mixing of it. Nowadays most of this work is done by humans so in order to prevent health hazards and other accidents from occurring, we can use Slag remover for better safety and fast work.

KEYWORDS: Hydraulic Slag Remover, Slag Remover Design & Its Design Calculations

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Original Article

1. INTRODUCTION

Slag remover is the hydraulically operated equipment which is used to remove the slag formed during the process of burning of raw material in the furnace to form in the molten state. Slag is the glass like by-product left over after the desired metal has been separated from its raw ore. Various types of slags are generated as waste material or byproduct in the metallurgical process. Based on its origins and characteristics, the main slags can be categorized into three major types, such as ferrous slag, nonferrous slag, and incineration slag. Slag usually contains quantities of valuable metal.

Nature contains different types of impurities like iron, copper, lead, nickel and other metals which are found in contaminated states called ores, often oxidized are mixed in with silicates of other metals. During smelting, when the ore is exposed to high temperatures, these impurities are separated from the molten metal and can be removed. Slag is the collection of compounds that are removed. Many smelting processes, oxides are introduced to control the slag chemistry, supporting in the removal of impurities and protecting the furnace refractory lining from excessive wear.

2. EXPERIMENTAL SETUP

Slag remover is made of steel material, here we can use steel for better strength of the material and it should not melt while carrying slag so we can use some ceramic coating for more strength in the scoop. Due to this, we get more strength and thus the life of product increases, like suppose if it works for 10 cycles then after coating it can be increased from 13 to 15 cycles also. Steel is a greatly corrosion-resistant material that can be

used structurally, particularly where a high-quality surface finish is required. Most steel has other metals added to adjust its properties, like strength, corrosion resistance, or affluence of fabrication. Steel is just the element iron that has been processed to control the amount of carbon. Iron, out of the ground, melts at around 1510 degrees C (2750°F). Steel often melts at around 1370 degrees C (2500°F). The stress-strain behavior of Steels differs from that of carbon steels in a number of respects.

The CREO Software is being used for my design; here you can observe the assembly of my project design. Generally, it is the assembly of more than ten parts. At first, I have designed each individual part with required dimensions and then after completion of each part design, I have assembled it. Few parts are designed ideally and few with reference to the parts available in the market like Electric motor, Hydraulic pistons, Pins for mounting and location for motor etc. Below is the assembly consists of parts like electric motor, swivel bearing, Gearbox, base plate, long cylindrical tube, and two different sized pistons, scoop and roboticarm.

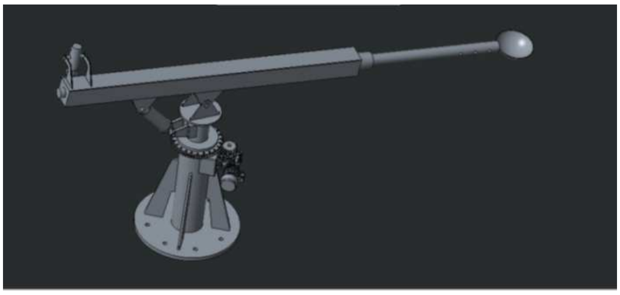

Figure 1: The Photograph of the Experimental Setup

3. THEORETICAL ANALYSIS

3.1 Design Calculations for the Required Parameters

- Scoop (semi-sphere)
- Robotic Arm frame
- Pins
- Body of equipment, two hollow tubes
- Base plate
- Bearing
- Pistons of 350mm and 250mm Stroke length
- Electric motor

Scoop

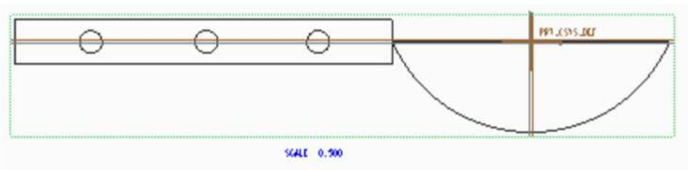

Figure 2

Diameter = 400 mm

Its radius =200 mm

Volume (V) $=\left(\frac{2}{3}\pi r^3\right)$ mm^3

Hollow Hemispherical scoop volume can be calculated by

Amount of iron used = volume of the outer hemisphere – volume of the inner hemisphere

$= \frac{2}{3}\pi r_2{}^3 - \frac{2}{3}\pi r_1{}^3$

$=\frac{2}{3}\pi(r_2{}^3 - r_1{}^3)$

$=\frac{2}{3}\pi(200^3 - 196^3)$

Volume $=98.5\times10^4 mm^3$.

Weight = (ρ×V×g) Newton

$= 7.85\times10^{-3} \times 9.81\times10^{-3}\times 98.5\times10^4$

Weight (W) = 75.85 N (1)

Now Weight of Cylinder Holding the Scoop

Figure 3

$\therefore V = \pi r2h = \pi\times302 \times 5002$

$V = 1.4\times10^6$ mm^3

Weight = (ρ×V×g)

$= 7.85\times10^{-3}\times9.81\times10^{-3}\times1.4\times10^6$

=107.81 N (2)

Total weight = W_1+W_2

= 75.85+107.81

= 183.66 N.

Stress acting in it $= \frac{P}{A} = \frac{183.66}{2.8\times10^3}$ N/mm^2

Cross sectional area $A= \pi r^2$

r = 30,

$\therefore$ A = 2.8 $\times 10^3$ mm^2

σ = 0.066 N/mm^2

Change in length (ΔL) $=\frac{P\times L}{A\times E} = \frac{183.66\times 500}{2.8\times 10^3\times 210\times 10^3}$

ΔL= 1.56$\times 10^{-4}$.

Rectangular Frame

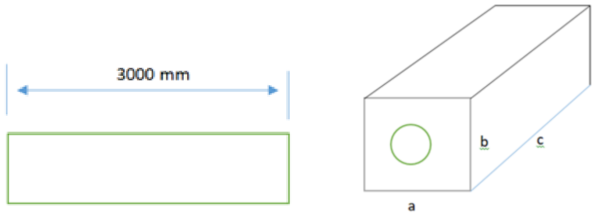

Figure 4

It is hollow, so

Volume of rectangular hollow tube =V_1-V_2.

V_1 is a rectangular frame.

V_2 is a circular hole.

V_1=L×B×H, mm^3

=200×200×3000

=12×107 mm3.

V2=πr2h mm3

= (50)2×3000

=97.2×105 mm3.

∴V=V1-V2 = (12×107)-(97.2×105)

V=110.3×106 mm3.

Weight =ρ×V×g

=7.85×10-3×9.81×10-3×110.3×106

∴W = 8.4×103 N.(3)

Stress (σ) $=\frac{P}{A}$

$=\frac{8.4\times 10^3}{4\times 10^4}$

$=0.21 {}^{N}/_{mm^2}$

Cross sectional area A =length × breadth.

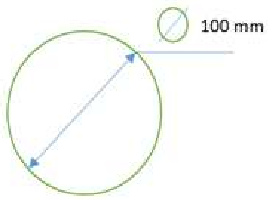

Figure 5

= 200×200

= 4×104 mm2

Change in length (ΔL)=$\frac{8.4\times10^3\times3000}{4\times10^4\times210\times10^3}$

ΔL=3×10-3.

Pins for Mounting

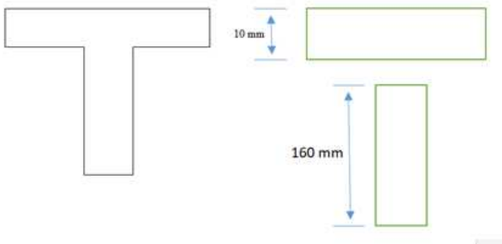

Figure 6

Total Volume **V**= V_1+V_2.

$V=\pi r^2h$.

$V_1=\pi r^2h$ $V_2=\pi r^2h$.

V_1=25 mm V_2=20 mm

V1= π (25)2×(10) V2= π (20)2×(160)

V1=19.6×103 mm3 V2=201×103 mm3.

∴V=V1+V2

= (19.6×103) + (201×103)

=220.6×103mm3.

Figure 7

Weight = $\rho \times V \times g$

$= 7.85\times10\text{-}3\times9.81\times10\text{-}3\times220.6\times103$

W = 16.9 N. (4)

Stress (σ) $=\frac{p}{A}$

Cross sectionalArea = $\pi r2$

$= \pi\ (20)2$

$= 1.2\times103$ mm2.

$(\sigma)=\frac{16.9}{1.2\times10^3}$

$= 0.014^{N}/_{mm^2}$..

Change in length $(\Delta L)=\frac{P\times L}{A\times E}$

$=\frac{16.9\times160}{1.2\times10^3\times210\times10^3}$

$=1.073\times10\text{-}5.$

Factor of safety = $\frac{\text{yield Stress}}{\text{working Stress}}$

$= \frac{250}{0.014}$ ΔL= 17,857.14 cycles.

Body of Equipment, Hollow Tubes,

Base Tube 1

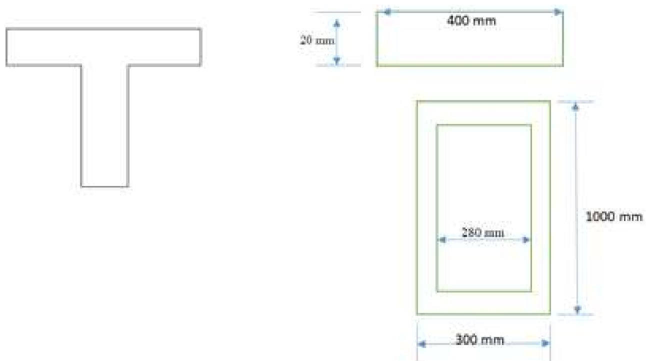

Figure 8

Volume=V1+V2.

$V1=\pi r2h$ $V2=\pi h(R2-r2)$

V1=200 mm $V2=\pi h\ (1502-1402)$.

$V1=\pi\ (200)2\times 20$ $V2=9.1\times 106$ mm3.

∴Volume =V1+V2

$= (2.5\times 106) + (9.1\times 106)$

$=11.6\times 106$ mm3.

Weight = $\rho\times V\times g$

$= 7.85\times 10\text{-}3\times 9.81\times 10\text{-}3\times 11.6\times 106$

W = 893.3 N.(5)

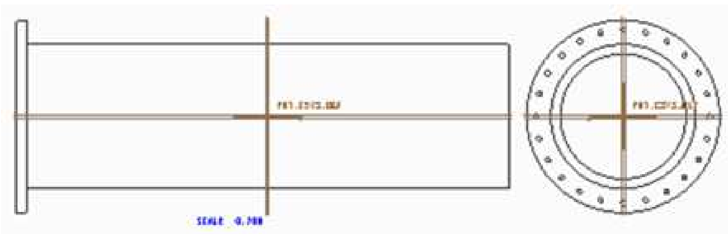

Figure 9

Stress (σ) $=\frac{P}{A}$

$= \frac{893.3}{70.6\times 10^3} = 0.013 {}^{N}/_{mm^2}$.

Cross sectionalArea = $\pi r2$

r =150 mm

$= \pi\ (150)2$

$= 70.6\times 103$ mm2.

Change in length (ΔL)$=\frac{P\times L}{A\times E}$

$=\frac{893.3\times 1000}{70.6\times 10^3\times 210\times 10^3}$

$\Delta L=6.03\times 10\text{-}5$.

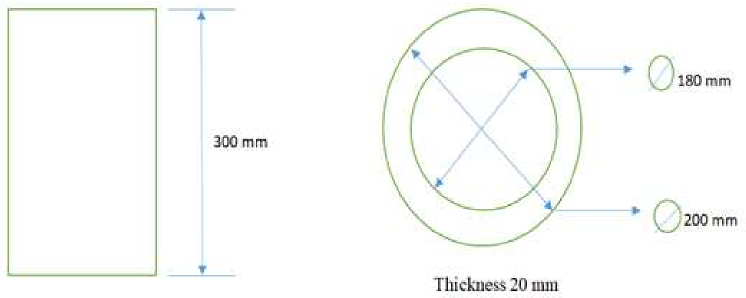

Figure 10

Base Tube 2,

Volume = πh (R2-r2)

R=100, r=90

= π×300× (1002-902)

∴Volume =17.9× 105 mm3.

Weight = ρ×V×g

= 7.85×10-3×9.81×10-3×17.9×105

W = 137.8 N.(6)

Stress σ = $\frac{P}{A}$

Cross sectional Area = πr2; r=100 mm

A = π (1002) = 31.4×103 mm2.

σ = $\frac{137.8}{31.4\times10^{3}}$

∴σ = 4.39 ×10-3 N/mm2.

Change in length (ΔL)=$\frac{4.39\times10^{-0}}{210\times10^{3}}$

ΔL=2.09×10-8.

Pistons Details

Now,

Follow the steps for remaining parts and finally, we get the total weight of the equipment.

Weight of large piston is 60.81 N.

Weight of small piston is 37.26 N.

And

weight of 1 HP electric motor is 142.34 N

Therefore from the above equations, we can Estimate the weight of total Equipment is the Sum of the weights of

each part.

Weight =183.66 + 8.4×103 + 16.9 + 893.3 + 2.27 × 103 + 137.8 + 60.81 + 37.26 + 142.34

∴Weight = 12,142.07 N

Analysis Part of Slag Remover

The procedure for a static analysis consists of three main steps:

- Build the model.
- Apply loads and obtain the solution.
- Review the results.

Stresses onSlag Remover Arm

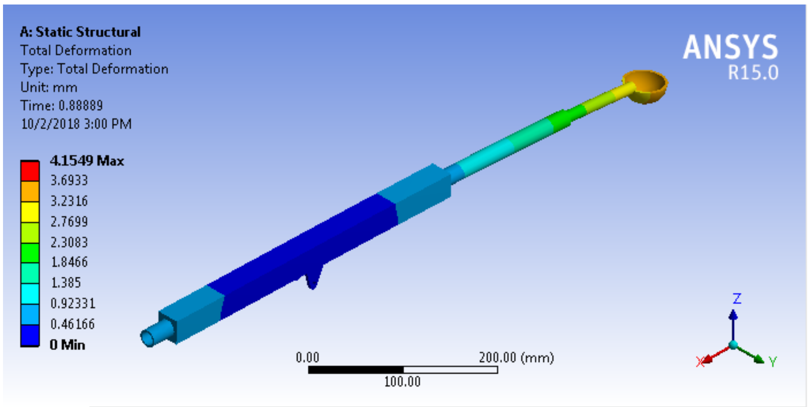

Figure 2: Stresses on Slag Remover Arm

Specifications

The following dimensions are used for this problem:

Width across flats = 30 mm

Configuration = Rectangular

Length of arm = 700 mm

Length of scoop = 200mm

Bend radius = 1 mm

Young's Modulus of steel= 210 GPa

Applied downward force = 183.66N.

Stresses on Base Tube

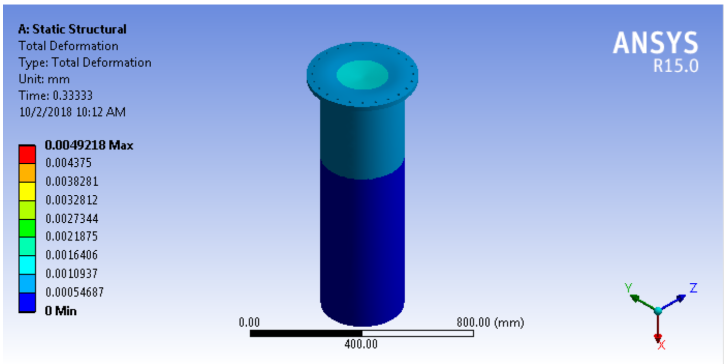

Figure 3: Stresses on Base Tube

Specifications

The following dimensions are used for the above problem:

Diameter of the tube = 300 mm

Configuration = Circular

Length tube = 1000 mm

Length of top head cover = 20mm

Bend radius = 1 mm

Young's Modulus of steel= 210 GPa

Applied downward force = 8,902.6N.

Stresses on Pin

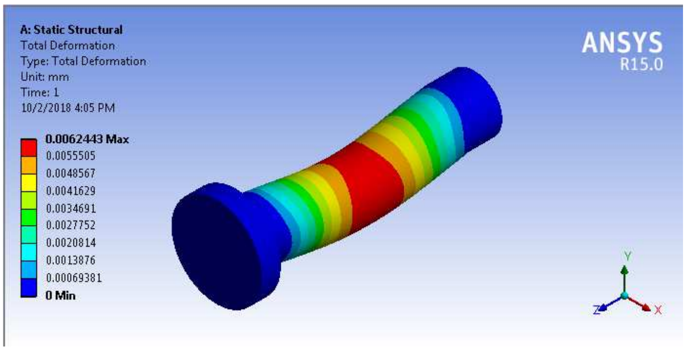

Figure 4: Stresses on Pin

Specifications

The following dimensions are used for the above problem:

Width of the body = 20 mm

Configuration = Circular

Length of pin= 170 mm

Bend radius = 1 mm

Young's Modulus of steel= 210 GPa

Applied downward force = 8583.66N.

4. CONCLUSIONS

Based on studies about the temperature availability and health hazards of humans due to accidents occurred near the combustion chamber, Slag remover is best to test rig to prevent the accidents and have better margin related to profit and work, time-consuming is also reduced. So the design slag remover is best to use in all conditions to prevent accidents, loss of labor and decrease in cost. Hence by replacing this equipment in the place of human, we can save the health hazards of human life and our environment can be protected.

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